

Saskatchewan Technology Enhancement Program

Crop and Summerfallow Area Estimation in Saskatchewan Using Landsat MSS Data for 1985

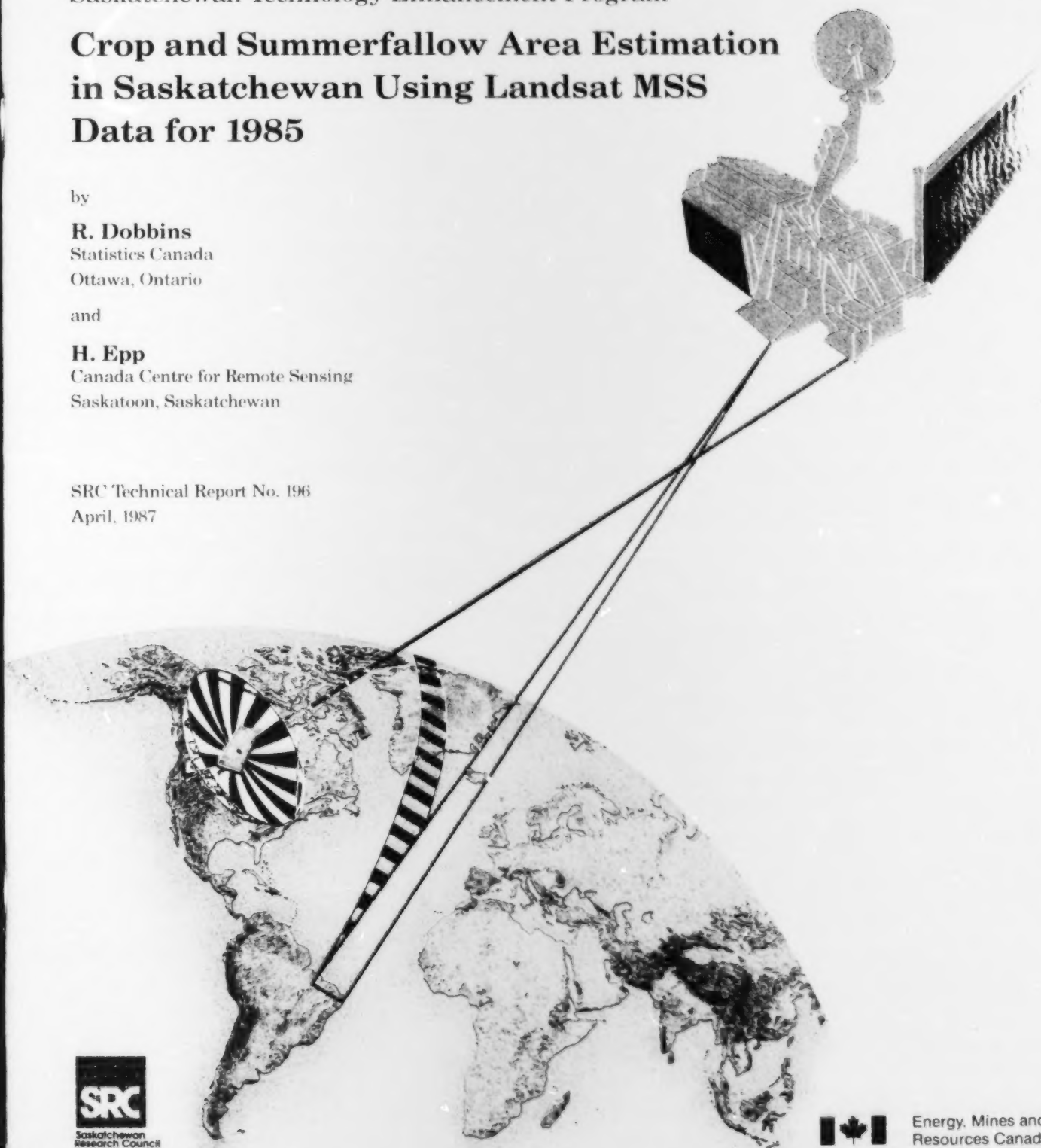
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April, 1987



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ABSTRACT

Since the early 1980's, Statistics Canada has been effectively employing remote sensing techniques as a complementary data source for generating crop area statistics. Cooperative federal-provincial multi-agency programs have been established whereby Landsat satellite data has been used to estimate the area of specific crops and summerfallow in each of the three Prairie Provinces.

This paper reports the results of the 1985 remote sensing crop and summerfallow area estimation project in Saskatchewan. The project demonstrated that operational methodologies developed elsewhere to estimate crop and summerfallow area using satellite data could be effectively transferred into the crop reporting system in Saskatchewan.

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Canada where ongoing operational and systems management support for image analysis operations was provided.

The views expressed in this report reflect those of the authors and do not necessarily convey those of either Statistics Canada or any of the participating agencies who were involved with this project.

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1. INTRODUCTION

Since 1981, Statistics Canada has been using remote sensing technology to estimate the area of specific target crops and summerfallow in Western Canada. Multi-agency federal/provincial cooperative programs have since been established, whereby Landsat multi spectral scanner (MSS) satellite data has been digitally processed and integrated with sound statistical techniques, in generating crop area and land use statistics. These programs, which are considered fully operational, evolved from procedures developed by Statistics Canada in concert with the Canada Centre for Remote Sensing, in earlier work which involved estimating potato area in New Brunswick (Ryerson et al. 1983, 1985).

Encouraged by the successful results obtained using this technique in other areas, a demonstration was initiated in 1985 whereby

crop and summerfallow area estimates would be generated in Saskatchewan using Landsat satellite data. This program, which fell under the auspices of the Saskatchewan Technology Enhancement Program (STEP), involved cooperative efforts from Statistics Canada, the Canada Centre for Remote Sensing, the Saskatchewan Research Council, and Saskatchewan Agriculture. The target region for the study was agriculture crop districts 7A and 7B, Saskatchewan, and the target cover types of interest were summerfallow, cereal grains, and canola-rape seed.

Results from this project clearly indicated that by using the methodology described, Landsat MSS satellite data could be used to generate crop and summerfallow area statistics with acceptable levels of accuracy in Saskatchewan.

2. SASKATCHEWAN TECHNOLOGY ENHANCEMENT PROGRAM (STEP)

In 1984, the Canada Centre for Remote Sensing (CCRS) signed a Memorandum of Understanding for Cooperation in remote sensing, the Technology Enhancement Program (TEP) with Saskatchewan was to assist the province in developing its scientific and technical capabilities in the application of remotely sensed data. Under the terms of this cooperative program several remote sensing projects, including the 1985 crop and summerfallow area es-

timation study, were initiated to demonstrate the useful role of remote sensing technology. The objective of the Saskatchewan Technology Enhancement Program (STEP) was to introduce remote sensing technologies to provincial natural resource managers. The ultimate aim was to have the technology adopted by government resource agencies as one of their standard methods of data collection and analysis.

3. 1985 CROP AND SUMMERFALLOW AREA ESTIMATION PROJECT

3.1 Project Objectives

The objective of the crop and summerfallow area estimation project was to demonstrate the effectiveness of Landsat MSS data for providing crop area statistics and land cover data in Saskatchewan.

The goal of the work was to provide acceptable area estimates for total cereal grains, canola-rapeseed and summerfallow in crop districts 7A and 7B, using Landsat MSS data. For the purpose of this study, total grains included durum wheat, spring wheat, oats, spring rye, barley and mixed grains.

Estimates of area would be used by Statistics Canada and Saskatchewan Agriculture crop analysts, in preparing official acreage estimates, which are published by Statistics Canada of each province. Thus, the estimates would be used in the decision making process by analysts, as an additional set of agriculture statistics which would complement more traditionally obtained survey data.

Provincial staff would derive the following benefits from this program:

1. increase in existing expertise to handle satellite data for resource management purposes;
2. enhanced knowledge as to what satellite (i.e. Landsat) data could provide in terms of crop and land cover statistics;
3. evaluation of the technology to determine if remote sensing techniques are applicable to location conditions;
4. evaluation of the economic and cost effectiveness of using satellite data for crop area estimation.

3.2 Description of the Study Region

The study region for the project was west central Saskatchewan, crop districts 7A and 7B (Figure 1). The region was chosen because a significant portion of it is devoted to spring grains, summerfallow and rapeseed production, with rapeseed being mainly concentrated in crop district 7B. A secondary consideration was that a single Landsat MSS scene of $185 \times 185 \text{ km}^2$ covered approximately 90% of the entire study area. The study area involved approximately $60,000 \text{ km}^2$ with the western edge being the provincial border with Alberta and the northern limit the South Saskatchewan River at North Battleford. Major urban centres in the region were Wilkie, Rosetown, Kindersley and Biggar.

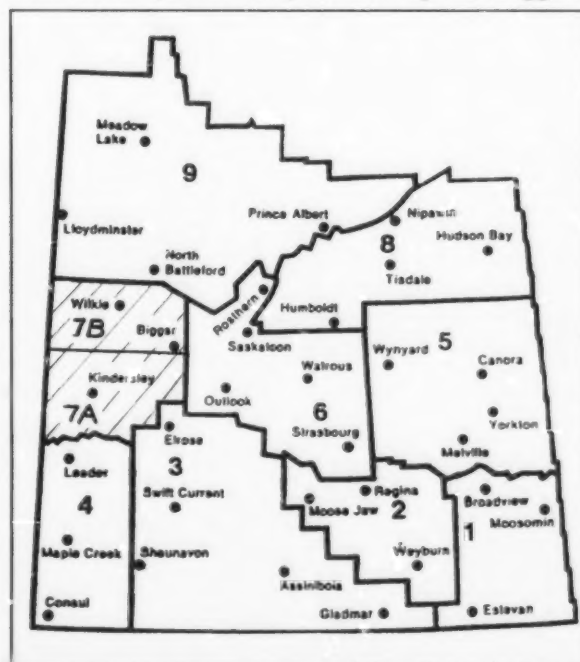


Figure 1. Location of Crop District 7 in Agricultural Saskatchewan.

3.3 Multi-Agency Cooperative Project

The roles of, and the contributions made by, each of the cooperative agencies who took part in this demonstration project varied widely. All inputs however, were important in assuring that the project progressed smoothly and as planned.

The roles and responsibilities of each of the participating agencies were as follows:

1. Statistics Canada provided overall project coordination and leadership, field support, statistical methodology support, funding for Landsat data, performed Landsat digital image analysis, and conducted liason with provincial agriculture contacts.
2. Under the term of the Saskatchewan Technology Enhancement Program, the Canada Centre for Remote Sensing provided remote sensing expertise in support of the project, and provided access to a DIPIX Systems Ltd. digital analysis system in Ottawa, which was used during the preprocessing phase of the project.
3. The Saskatchewan Research Council (SRC) in Saskatoon represented Saskatchewan provincial interests in the program, assisted in an advisory role, and gave priority consideration for the use of image analysis equipment housed at SRC.
4. Saskatchewan Agriculture (Economics Branch) provided advisory support and initiated further support from Saskatchewan Agriculture field staff. Saskatchewan Agriculture field representatives monitored crop conditions within the study region for this project throughout the growing season and reported on general weather conditions on the days of satellite overpass.

Additional support was provided by many others within Statistics Canada. These people were responsible for a wide range of duties, from training field staff to mapping selected NFS ground segments and generating the statistical estimates.

4. METHODOLOGY

4.1 General Approach

The project procedures stem from previous work which used Landsat MSS data in combination with ground-gathered information (Horn et al. 1983, 1985; Ryerson et al. 1983, 1985). The work involves the integration of Landsat MSS data with ground-gathered calibration data and a linear regression estimator (Figure 2).

Landsat MSS computer tapes were processed to produce raw classification totals for each of the three target cover types. A probability-based agriculture enumerative survey (National Farm Survey) provided ground information which was used to "train" an image analysis system to recognize the spectral reflectance values of the target cover types.

After computer classification, a linear regression was used to develop the statistical relationship between the Landsat classification and ground information essential for determining the classification accuracy and variance. The combination of both ground and satellite information was then used to derive a final regression area estimate for each target cover type.

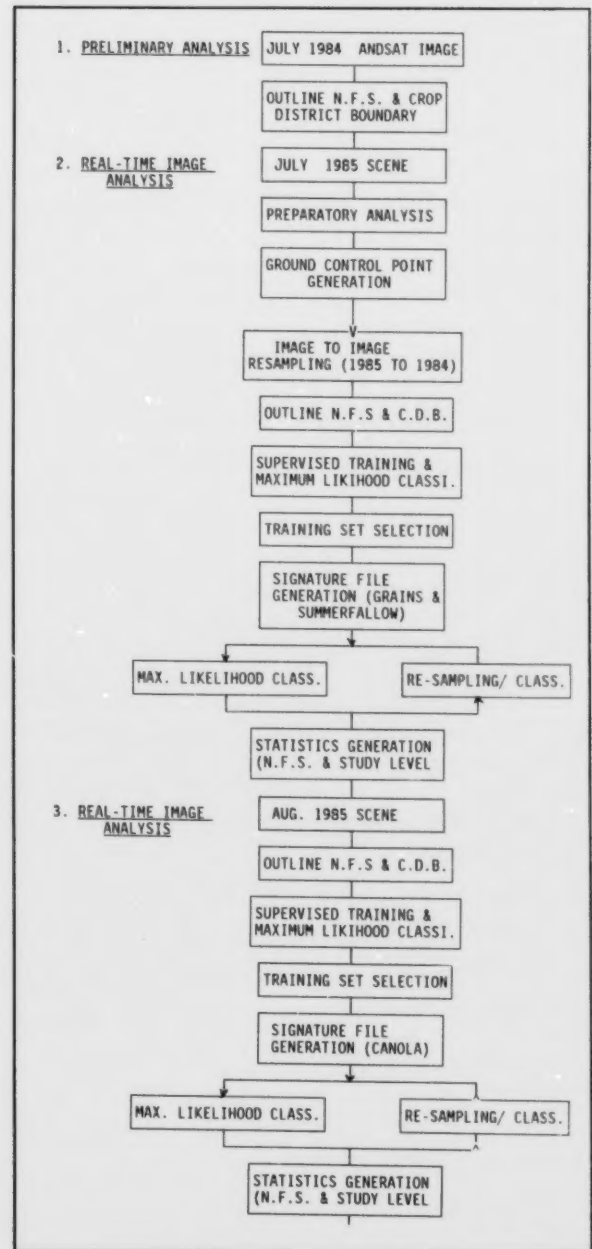


Figure 2. Flowchart of Image Analysis Procedure.

5. PLANNING AND ORGANIZATION

To make Landsat useful for providing of crop area estimates in Saskatchewan a systematic, well organized, and precisely followed management plan was established (Dobbins et al. 1983).

Preparatory planning and organization involved pre-Landsat computer image analysis in advance of acquiring both ground-gathered data and Landsat computer compatible tapes.

Upon completion of interdepartmental agreements, joint planning, which established the extent and nature of support of each participating

department/agency, began. Detailed joint planning included defining responsibilities of respective staff, and developing strategies in controlling the schedule of all inputs.

In addition, to ensure that the project's objectives, and moreover the respective duties of all participating agencies were clearly understood, a one-day seminar/workshop, was given by Statistics Canada and CCRS project staff at the Saskatchewan Research Council in Saskatoon in May, 1985.

6. GROUND DATA ACQUISITION (NATIONAL FARM SURVEY)

Ground data were obtained by enumerators from a random sample of land segments as part of Statistics Canada's National Farm Survey (NFS). Using 1981 Census of Agriculture information, a random sample of NFS segments were selected in late 1984 and mapped onto 1:250,000 National Topographic System (NTS) mapsheets. NFS enumerators were supplied with enlarged aerial photographs for individual segments, each covering 1 x 3 miles. There were 38 segments selected within the study area, 21 of which were in district 7A and 17 in 7B. Within each land segment, field boundaries, crop type and acreages were recorded on the photographs as reported by the farm owners. Once completed, a quality analysis of each segment was

completed to ensure accuracy and consistency of the ground data set. The NFS ground data was then used to:

1. "train" the classification algorithm to recognize the spectral signatures of crops of interest during computer image processing;
2. assess the performance of the crop classification by comparison with known field data;
3. provide an auxiliary variable in the regression estimation procedure;
4. calculate coefficient of variation.

7. LANDSAT DATA ACQUISITION

7.1 The Landsat Series

The satellite data used in this project were obtained from the Landsat series of earth resource satellites. Landsat carries a multi spectral scanner (MSS) which records reflected energy from the earth's surface. The reflected energy is separated into four distinct portions of the electromagnetic spectrum with two bands in the visible and two in the near infrared portion. The resolution of the MSS sensor is 80 m, which in general terms means that all objects larger than 79 m in size are distinguishable.

Landsat continuously records this digital information and transmits, in near real-time, an image of the earth below. Each image is approximately 185 x 185 km in area, or 34,000 km². Landsat scenes are composed of grid cells or pixels, each of which are approximately 79 x 59 m in size or 1.1 acres. Because the data is recorded simultaneously in each of the four spectral bands in digital format, images can be processed into computer readable formats. Processing of the raw Landsat information is conducted by the Canada Centre for Remote Sensing at the Prince Albert Satellite Receiving Station (PASS) in Saskatchewan. Landsat imagery is available to customers in the form of computer compatible tapes (CCT's) or as photographic products.

7.2 Project Requirements for Landsat Data

To effectively use Landsat MSS data operationally for crop area estimation, the following conditions for data acquisition must be satisfied. First, the crops of interest have to be spectrally distinguishable at the time of the satellite pass, and second, the scenes should be 80 to 90% cloud free. In an operational environment there is an additional consideration; there must be an acceptable period between the time

the satellite records an image and the arrival of the satellite tape on the desk of the user.

Rapeseed can be spectrally separated from other crops when it is in flower (Brown et al. 1980). Cereals can be most reliably separated from other crops when the grains have progressed into the jointing stage (Ryerson 1983). This period of time is commonly referred to as the biological window. Crop reports issued by Saskatchewan Agriculture indicated that in 1985 the biological window for rapeseed in the study area was between July 10 and August 10. Reports also indicated that most of the cereals planted in the study region had reached the heading stage by the last week of July.

To ensure timely delivery of the Landsat MSS computer tapes, a standing order was placed with the Prince Albert Satellite Station (PASS), in advance of summer analysis. All tapes were geometrically and radiometrically processed at PASS with corrections made for earth curvature and rotation and mirror velocity.

7.3 Real-Time Landsat Data Acquisition

A July 5, 1985 image (Track 39, Image Centre 24) was obtained which covered most of both crop districts 7A and 7B. Extensive cloud cover, however, obscured the northern portion of the scene where most of the rapeseed was planted. Although the optimum period for classification of rapeseed using Landsat MSS data occurs when the crop is in the flowering stage, to avoid a "bottleneck" in processing other Landsat tapes for other Statistics Canada projects, a decision was made to obtain the July 5, 1985 scene in a rush mode whereby the CCT was obtained within 48 hours of being recorded and process it for cereals and fallowland alone. A second image was then required to generate a separate area estimate for rapeseed. On August 6, 1985 a second image of the study area was recorded.

When ordering Landsat tapes, users may request that the image data be framed either according to the standard track and image centre or offset in the along-path direction to ensure

complete coverage of the area of interest. The August 6 scene was offset by minus five seconds to ensure that the scene would completely cover all of crop district 7B.

8. LANDSAT DIGITAL IMAGE PROCESSING

In preparation for the image analysis, a July 18, 1984 Landsat MSS tape of the study region was purchased in the spring of 1985. Using a DIPIX ARIES II¹ image analysis system, NFS segments and crop district boundaries were outlined on this image. Once the current July 5, 1985 scene had been obtained, it was then resampled to precisely overlay onto the historic 1984 scene of the same area. By so doing, NFS segments and crop district boundaries were simply "called-up" from disc, without spending time to outline these polygons during analysis.

The main procedure in the image processing step is commonly referred to as supervised classification. Picture elements (pixels) with similar spectral characteristics are grouped into classes. The assumption is that each crop of interest is spectrally separable from other crops.

Training set selection is an interactive process whereby the image analyst must adequately identify and create a representative training set for each of the target cover types. The fields chosen for inclusion in the training set were selected using the NFS segments. National Farm Survey aerial photo mosaics provided site-specific information and acreage.

To ensure that a representative sample of fields were contained within each training set, several fields, each possessing dissimilar colours on the displayed Landsat image were included. Every attempt was made to include a true representation of the spectral reflection properties

for each of the target crops within the entire Landsat scene.

In order to build upon training sets a fast parallel piped classification was employed, where, using a cursor, the analyst indicated single pixels or delineated groups of pixels considered representative of a class or cover type. Based on this outlining of pixels, a classification was generated and displayed in near real-time. The resulting classification was then assessed separately for each original classification. This iterative process was repeated until, based on a visual assessment, a satisfactory result was reached, thus furnishing an acceptable training set for subsequent signature files and maximum likelihood classifications.

A signature file based on each crop training set was produced which consisted of the number of pixels, the mean values, standard deviation, covariance matrix and correlation coefficients between the satellite bands.

Using these signature files, a maximum likelihood classification was produced throughout a subarea (512 by 512 pixels) of the entire scene. The resulting classification was assessed by visually comparing the results with those NFS segments which were contained within the subarea. Once deemed acceptable, a maximum likelihood classification was then extended to the entire Landsat scene using the identical signature files which were used in the classification of the subarea(s).

1) Mention of or failure to mention commercial trade names does not imply endorsement or criticism by the Government of Canada or the Government of Saskatchewan.

9. ACCURACY ASSESSMENT

Accuracy assessment involved identifying problem areas following image analysis. Once completed, the classification results were viewed on the colour display monitor. Classification results were separately displayed and assessed by comparing the computer classification with ground information for each segment. For each of the NFS segments contained on the Landsat image, NFS ground data was plotted against classification results which identified outliers in the computer classification. A visual assessment of segments throughout the entire scene

was made, making note of different soils, climates and physiological patterns which may have impacted on the classification results. Any significant variability between the classification and the reported ground information was treated as a statistical outlier. NFS segments in which the classification was not adequate were identified. Problem fields within these segments were examined and in some instances, on-site verification by Saskatchewan Agriculture field representatives was required.

10. STATISTICAL ESTIMATION PROCEDURE

10.1 Regression Estimator

The method of combining satellite data with survey data, first developed and applied in the United States, has a proven record for producing more accurate results than either satellite or survey data alone.

To produce a satellite-derived area estimate for rapeseed, cereal grains and summerfallow a regression estimator was used. The estimator combined the crop classification results with the ground data provided by the National Farm Survey. The assumption is that the crop areas measured by the satellite related to the true area, the same as crop areas measured by the satellite for each of the NFS segments relate to the reported or true areas for those segments.

The area estimate of a crop from the NFS and the pixel count from the Landsat classification were extracted for each segment and used with the total number of pixels classified in the target region to build a regression estimator. Estimates, along with their variances, were calculated using the NFS sample design. Since the NFS is designed to produce estimates for livestock and farm expenses not related to those studied by remote sensing, it was necessary to use the technique of post-stratification to better accommodate the needs of the remote sensing project.

Since the entire study region was not covered by a single Landsat scene, it was necessary to define the part of the study region to be es-

timated using the regression technique. The missing part was estimated by applying a change ratio using 1981 Census of Agriculture data.

The regression estimate of Y, the total area of the target type in the regression region is calculated as:

$$\hat{Y}_{reg} = \hat{Y} + \hat{B} (\hat{X} - X)$$

The number of pixels classified for the target type in the regression region. $\hat{X}$ and $\hat{Y}$ are estimates of X and Y using data at the segment level and the NFS sample design. B is the regression coefficient which reflects the relation between the pixel count and the ground data for the crop of interest. The regression estimator corrects the direct satellite pixel count for under or over-classification using this relationship. The regression area estimates for cereal grains and summerfallow were produced using 28 NFS segments.

The final regression area estimate for rapeseed in crop district 7B was produced using classification results from 17 of the total 38 NFS segments which were covered by the August 6, 1985 scene. Of these 17 segments, four segments reported zero rapeseed acreage by both data sources. The area estimate was therefore calculated by applying a change ratio using 1981 Census of Agriculture data to input for that portion of the area which was not covered by the Landsat image.

11. RESULTS: CROP AND SUMMERFALLOW AREA ESTIMATES

The results of this project in 1985 are given in Table 1. The final regression area estimates for both cereal grains and summerfallow were made available to crop analysts prior to release of Statistics Canada's publication "September Forecast of Production of Principal Field Crops, Canada." Similarly, final regression area estimates for canola-rapeseed in crop district 7B were produced prior to release of Statistics Canada's crop reporting publication "November Estimate of Production of Principal Field Crops, Canada."

Table 1.
1985 Remote Sensing Survey Results for Crop Area
Estimates in Saskatchewan.

Target	Survey Estimate	Survey Estimate (Acres)
Canola-Rapeseed	Remote Sensing	146,000
	Crop Reporting*	115,000
Cereal Grains**	Remote Sensing	2,500,000
	Crop Reporting	2,500,000
Summerfallow	Remote Sensing	1,600,000
	Crop Reporting	1,750,000

* Crop reporting panel: Statistics Canada June Acreage Survey (pro-rated).

** Cereal Grains included spring and durum wheat, oats, barley, spring rye, and mixed grains.

12. DISCUSSION

12.1 Landsat Image Processing

The image analysis procedure used in producing a classification for grains, rapeseed and summerfallow was similar with some minor differences. A separate signature file for the July 5, 1985 Landsat image was used for grains and summerfallow. Three separate signature files were required so that there would be greater separation between cereal grain pixels and confusion pixels. Cereal grains are commonly confused with native pasture and bushland on mid-summer Landsat MSS imagery. A multi-signature classification was used since it is more time- and computer-effective than when generating a maximum likelihood classification from only one signature file.

The maximum likelihood classification for rapeseed developed from the August 6, 1985 Landsat scene was based on only one signature file. That was done since there was no indication of confusion with other signatures.

Not all NFS segments or fields within the segments were used to train the classifier. But all NFS segment data which were covered by the Landsat image were used to obtain the regression area estimates. Ideally, the data set upon which the regression is developed should be independent from that used for training the classifier.

12.2 Impact of Drought

Large areas of southwestern Saskatchewan were severely affected by a drought during the

summer of 1985. The effect of the drought was evident on both the July 5 and August 6 Landsat images. Some of the crops died at the seedling stage which had an impact on the performance of the resultant crop classification for cereal grains. Fields where the seedlings had died were classified as fallow. Area estimates of cereal grains, therefore, should closely reflect harvested acreage.

12.3 Filtering

After the classification process a number of single pixels scattered throughout the image remained unclassified. To improve the aesthetic quality of the classification, a post classification filter was used to both remove these extraneous pixels and also to fill in any gaps.

To test the strength of the NFS-based regression, a 3 x 3 boxcar filter was applied to the initial rapeseed classification. Separate regression estimates were then produced using both the filtered and unfiltered classifications. The regression estimates were compared but there were no significant differences as indicated in Table 2.

Table 2.
Canola-Rapeseed Area Estimates Using Filtered and Unfiltered Data for Crop Districts 7A, and 7B.

	Remote Sensing Regression Estimate (Acres)	Total Classified Pixels
Filtered data	146,557	80,120
Unfiltered data	147,557	94,752

13. SUMMARY AND CONCLUSIONS

The 1985 Saskatchewan remote sensing crop and summerfallow area estimation program clearly demonstrated the following:

1. Using Landsat MSS data in combination with ground data and a linear regression estimator, area estimates for canola-rapeseed, total cereal grains, and summerfallow were obtained. Results of the study were most encouraging, and plans have been made to conduct a follow-on program which will be expanded to several more crop districts in 1986.
2. This project clearly demonstrated that Landsat data can be used in conjunction with a statistically sound sample design and estimation procedure to generate crop area statistics. This cooperative project can serve as a catalyst in paving the way for developing a full scale operational crop area estimation program which can accommodate information requirements for the crop reporting system in Saskatchewan.
3. If near real-time data is available in an operational system, first estimates of seeded spring grains and summerfallow can be produced using remote sensing technology as early as mid-July.
4. Interest now exists in determining the earliest date on which an accurate area estimate for spring grains and summerfallow can be generated.
5. Although the contributions of each agency were varied, each served a vital function in determining the successful outcome of the project.
6. Further technological developments can lead to large scale adoption of remote sensing techniques for monitoring crop statistics in Saskatchewan.

14. RECOMMENDATIONS

Whereas the success of the 1985 crop and summerfallow area estimation project was a first year demonstration study, it may be considered by some as a start towards the development of an expanded operational program in Saskatchewan. In recognition of the fact that project costs associated with follow-on work reduce as improvements in program efficiency develop, the following recommendations are made.

1. All efforts be made in controlling the increasing costs of purchasing Landsat MSS digital data, so that programs such as this remain operationally manageable.
2. Any follow-on projects, involving crop area

estimation using Landsat, involve cooperative efforts whereby through "pooling" of resources and expertise, project costs are not absorbed by one agency alone. Benefits obtained through the use of remotely sensed data must be readily available to both federal and provincial interests alike.

3. Any follow-on projects involving crop area estimation using Landsat must be based on a sound statistical framework and estimation procedure, thus ensuring that the results obtained by Landsat alone are not misinterpreted by the end users.

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